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INVENTORS: Yukio Ohtaki
Kouta Iijima
Takeo Suzuki

TITLE: OFDM Receiver for Easily
Synchronizing Base Band Signal

ATTORNEY: Gustavo Siller, Jr.
BRINKS HOFER GILSON & LIONE
P.O. BOX 10395
CHICAGO, ILLINOIS 60610
(312) 321-4200

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SPECIFICATION

TITLE OF THE INVENTION

OFDM receiver for easily synchronizing base band
5 signal

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to an OFDM receiver for
10 receiving an OFDM (Orthogonal Frequency Division
Multiplexing) modulated high frequency signal by diversity
synthesis, and particularly relates to an OFDM receiver
suitably used in a television receiver for car mounting.

DESCRIPTION OF THE RELATED ART

15 Fig. 4 shows a conventional OFDM receiver. In Fig. 4,
plural antennas (shown in the case of four antennas) 111,
121, 131, 141 for receiving an OFDM modulated high
frequency signal are arranged in places separated from
each other on a vehicle as one example. Receiving portions
20 112, 122, 132, 142 are correspondingly connected to the
respective antennas 111 to 141. The respective receiving
portions 112 to 142 have the same construction, and
frequency-convert the high frequency signal to be received
to an intermediate frequency signal. A/D converters 113,
25 123, 133, 143 are connected to the next stages of the
respective receiving portions 112 to 142. Each A/D
converter converts the intermediate frequency signal to a

digital signal, and outputs a base band signal of a time area.

First to fourth OFDM demodulating means 114, 124, 134, 144 are connected to the next stages of the respective A/D converters 113 to 143. The respective OFDM demodulating means 114 to 144 have a high speed Fourier converter of the same construction therein, and perform conversion to the base band signal of a frequency area by performing Fourier transformation by taking synchronization of the base band signal of the time area.

A first phase control circuit 151 is connected between the output terminal of the first OFDM demodulating means 114 and the output terminal of the second OFDM demodulating means 124 among the above four OFDM demodulating means. A second phase control means 152 is connected between the output terminal of the first OFDM demodulating means 114 and the output terminal of the third OFDM demodulating means 134. A third phase control means 153 is connected between the output terminal of the first OFDM demodulating means 114 and the output terminal of the fourth OFDM demodulating means 144. A first phase shifter 154, a second phase shifter 155 and a third phase shifter 156 are respectively connected to the next stages of the second to fourth OFDM demodulating means.

The respective phase control means 151 to 153 have the same construction, and respectively compare the phase of the base band signal of the frequency area outputted

from the second to fourth OFDM demodulating means 124, 134, 144 and the phase of the base band signal of the frequency area outputted from the first OFDM demodulating means 114, and respectively output its phase difference signals to
5 the first to third phase shifters 154 to 156. Each of the phase shifters 154 to 156 outputs a base band signal of the frequency area conformed to the phase of the base band signal of the frequency area outputted from the first OFDM demodulating means 114 by changing the phase of the
10 inputted base band signal of the frequency area by each phase difference signal.

The base band signal of the frequency area outputted from the first OFDM demodulating means 114 and the base band signal of the frequency area outputted from the first
15 phase shifter 154 are added by a first adder 157. The base band signal of the frequency area outputted from the second phase shifter 155 and the base band signal of the frequency area outputted from the third phase shifter 156 are added by a second adder 158. A third adder 159 is
20 connected between the output terminal of the first adder 157 and the output terminal of the second adder 158. Accordingly, the base band signals of the frequency area outputted from all the OFDM demodulating means 114 to 144 are finally added by the third adder 159 in the same phase
25 relation. Accordingly, a base band signal having maximum signal electric power is obtained from the third adder 159. A bit error included in the added base band signal is

corrected by an error correcting means 160, and the corrected base band signal of the frequency area is outputted.

When there is an antenna greatly reduced in level of
5 the received high frequency signal by fading caused by
e.g., the movement of a mounted vehicle in the
conventional OFDM receiver, it is impossible to accurately
take the synchronization of the base band signal of the
time area in the OFDM demodulating means corresponding to
10 this antenna. In such a state, no Fourier transformation
can be also accurately performed by this OFDM demodulating
means so that no base band signal of electric power
sufficient to correct the error and corresponding to the
number of antennas can be obtained. Accordingly, the
15 problem of causing a reduction in image quality, etc. is
caused.

Further, since the expensive OFDM demodulating means
is arranged by the same number correspondingly with each
antenna, it has a disadvantage in that the receiver is
20 high in cost.

SUMMARY OF THE INVENTION

An object of the present invention is to reduce cost
by reducing the number of OFDM demodulating means, and
25 easily synchronize the base band signal of the time area
in the OFDM demodulating means.

Therefore, an OFDM receiver of the present invention

as a means for solving the above problems comprises four antennas or more for receiving an OFDM modulated high frequency signal, and plural OFDM demodulating means for inputting a base band signal of a time area thereto on the basis of the high frequency signal and outputting the base band signal of a frequency area, wherein the OFDM demodulating means are arranged every plural antenna groups with two or more of the antennas as one group, and a first phase shifter is arranged on the former stage side of each of the OFDM demodulating means, and a second phase shifter is arranged at the latter stage of another OFDM demodulating means except for a specific OFDM demodulating means among the OFDM demodulating means, and a signal is diversity-synthesized by the first phase shifter until the base band signal of the time area is inputted to each of the OFDM demodulating means, and the base band signal of the frequency area is diversity-synthesized by the second phase shifter.

Further, the base band signal of the time area based on the high frequency signal received by a specific antenna in each of the antenna groups, and the base band signal of the time area based on the high frequency signal received by another antenna except for the specific antenna are diversity-synthesized by the first phase shifter.

Further, a receiving portion for frequency-converting the high frequency signal to an intermediate frequency

signal, and an A/D converter for converting the intermediate frequency signal to a digital signal and outputting the base band signal of the time area are arranged every each of the antennas, and the first phase
5 shifter is arranged at the next stage of the A/D converter corresponding to the another antenna, and a first adder is arranged between the first phase shifter and the A/D converter corresponding to the specific antenna.

Further, the intermediate frequency signal based on
10 the high frequency signal received by the specific antenna in each of the antenna groups, and the intermediate frequency signal based on the high frequency signal received by another antenna except for the specific antenna are diversity-synthesized by the first phase
15 shifter.

Further, a receiving portion for frequency-converting the high frequency signal to the intermediate frequency signal is arranged every each of the antennas, and the first phase shifter is arranged at the next stage of the
20 receiving portion corresponding to the another antenna, and a first adder is arranged between the receiving portion corresponding to the specific antenna and the first phase shifter.

Further, the high frequency signal received by the
25 specific antenna in each of the antenna groups, and the high frequency signal received by another antenna except for the specific antenna are diversity-synthesized by the

first phase shifter.

Further, the first phase shifter is connected to the another antenna, and a first adder is arranged between the specific antenna and the first phase shifter.

5 Further, power detecting means for detecting electric power of the base band signal of the time area, and phase control means for controlling phase setting of the first phase shifter so as to maximize the electric power are arranged.

10 Further, the second phase shifter is arranged at the next stage of the another OFDM demodulating means, and a second adder is arranged between the specific OFDM demodulating means and the second phase shifter.

Further, the OFDM receiver further comprises phase
15 control means for controlling phase setting of the second phase shifter such that the phase of the base band signal of the frequency area outputted from the second phase shifter is conformed to the phase of the base band signal of the frequency area outputted from the specific OFDM
20 demodulating means.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram showing the construction of a first embodiment mode in an OFDM receiver of the
25 present invention.

Fig. 2 is a circuit diagram showing the construction of a second embodiment mode in the OFDM receiver of the

present invention.

Fig. 3 is a circuit diagram showing the construction of a third embodiment mode in the OFDM receiver of the present invention.

5 Fig. 4 is a circuit diagram showing the construction of a conventional OFDM receiver.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An OFDM receiver of the present invention will next
10 be explained in accordance with the drawings. Fig. 1 shows the construction of a first embodiment mode. Fig. 2 shows the construction of a second embodiment mode. Fig. 3 shows the construction of a third embodiment mode.

First, in Fig. 1, plural antennas (shown in the case
15 of four antennas) 11, 21, 51, 61 for receiving an OFDM modulated high frequency signal are arranged in places separated from each other on a vehicle as one example. Here, antennas 11 and 21 and antennas 51 and 61 belong to separate antenna groups. A receiving portion 12 and an A/D
20 converter 13 are sequentially cascade-connected to one specific antenna 11 in a first antenna group 1. A receiving portion 22, an A/D converter 23 and a first phase shifter 31 are sequentially cascade-connected to another antenna 21 except for the specific antenna 11. A
25 first adder 32 is connected to the output terminal of the A/D converter 13 and the output terminal of the first phase shifter 31. Here, the specific antenna 11 is

distinguished from another antenna 21 because no first phase shifter 31 is interposed between the first adder 32 and the A/D converter 13 corresponding to the specific antenna 11.

5 A power detecting means 33 and one specific OFDM demodulating means 35 are connected to the next stage of the first adder 32. A phase control means 34 is connected between the power detecting means 33 and the first phase shifter 31.

10 On the other hand, a receiving portion 52 and an A/D converter 53 are sequentially cascade-connected to one specific antenna 51 in a second antenna group 5. A receiving portion 62, an A/D converter 63 and a first phase adder 71 are sequentially cascade-connected to
15 another antenna 61 except for the specific antenna 51. A first adder 72 is connected to the output terminal of the A/D converter 53 and the output terminal of the first phase shifter 71. Here, similar to the above case, the specific antenna 51 is distinguished from another antenna
20 61 because no first phase shifter 71 is interposed between the first adder 72 and the A/D converter 53 corresponding to the specific antenna 51.

 A power detecting means 73 and another OFDM demodulating means 75 except for the specific OFDM
25 demodulating means 35 are connected to the next stage of the first adder 72. A phase control means 74 is connected between the power detecting means 73 and the first phase

shifter 71.

A third adder 93 is connected to the next stage of the specific OFDM demodulating means 35. A second phase shifter 92 is connected to the next stage of another OFDM demodulating means 75. A third adder 93 is connected to the next stage of the second phase shifter 92. Here, the specific OFDM demodulating means 35 is distinguished from another OFDM demodulating means 75 because no second phase shifter 92 is interposed between the specific OFDM demodulating means 35 and the third adder 93.

A phase control means 91 is arranged between the output terminal of the specific OFDM demodulating means 35 and the output terminal of another OFDM demodulating means 75, and its output terminal is connected to the second phase shifter 92.

In the above construction, the receiving portions 12, 22, 52, 62 mutually have the same construction, and convert the frequency of a high frequency signal to be received to the frequency of an intermediate frequency signal. The A/D converters 13, 23, 53, 63 also have the same construction, and convert the intermediate frequency signal to a digital base band signal of a time area. The first phase shifters 31, 71 also have the same construction. The power detecting means 33, 73 also have the same construction, and detect electric power of the base band signal of the time area. The phase control circuits 34, 74 also have the same construction, and

respectively control the operations of the first phase shifters 31, 71.

Here, the base band signal of the time area outputted from the A/D converter 13 corresponding to the specific antenna 11 is directly inputted to the first adder 32
5 corresponding to the first antenna group 1. On the other hand, the base band signal of the time area outputted from the A/D converter 23 corresponding to another antenna 21 is inputted through the first phase shifter 31. In this
10 case, the phase of the first phase shifter 31 is set by the phase control circuit 34 such that signal electric power detected by the power detecting means 33 becomes maximum. As this result, the phase of the base band signal of the time area inputted from the first phase shifter 31
15 to the first adder 32 is conformed to the phase of the base band signal of the time area directly inputted from the A/D converter 13 to the first adder 32. Namely, diversity synthesis is made at the stage of the base band signal of the time area. Accordingly, the base band signal
20 of the time area having maximum electric power is inputted to the specific OFDM demodulating means 35.

Similarly, the base band signal of the time area outputted from the A/D converter 53 corresponding to the specific antenna 51 is directly inputted to the first
25 adder 72 corresponding to the second antenna group 5. On the other hand, the base band signal of the time area outputted from the A/D converter 63 corresponding to

another antenna 61 is inputted through the first phase shifter 71. Similarly, the phase of the first phase shifter 71 is set by the phase control circuit 74 such that signal electric power detected by the power detecting means 73 becomes maximum. As this result, the phase of the base band signal of the time area inputted from the first phase shifter 71 to the first adder 72 is conformed to the phase of the base band signal of the time area directly inputted from the A/D converter 53 to the first adder 72. Namely, the diversity synthesis is also made at the stage of the base band signal of the time area in this case. Accordingly, the base band signal of the time area having maximum electric power is inputted to another OFDM demodulating means 75.

Accordingly, it is easy to take synchronization for Fourier-transforming the base band signal of the time area in the specific OFDM demodulating means 35 and another OFDM demodulating means 75. The base band signal of a frequency area is outputted from each of the OFDM demodulating means 35, 75.

At the stage up to now, the phase of the base band signal of the frequency area outputted from the specific OFDM demodulating means 35 and the phase of the base band signal of the frequency area outputted from another OFDM demodulating means 75 are not necessarily conformed to each other. Therefore, when the two base band signals of the frequency area are inputted to the third adder 93, the

phase of the base band signal of the frequency area
outputted from another OFDM demodulating means 75 is
conformed to the phase of the base band signal of the
frequency area outputted from the specific OFDM
5 demodulating means 35 through the second phase shifter 92.
This phase alignment is controlled by the phase control
means 91 for comparing the phases of the two base band
signals of the frequency area.

As this result, the base band signal of the frequency
10 area having maximum electric power is outputted from the
third adder 93, and is inputted to an error correcting
means 94. The error correcting means 94 corrects a bit
error included in the base band signal of the frequency
area, and outputs the corrected base band signal of the
15 frequency area.

Since the diversity synthesis is made at the stage of
the base band signal of the time area in the above
construction, it is possible to cope with four antennas 11
to 61 by using only two means constructed by the specific
20 OFDM demodulating means 35 and another OFDM demodulating
means 75. Accordingly, there is an effect of a reduction
in cost.

When the number of antennas is increased, the
increased antennas are taken into the existing first
25 antenna group 1 or the existing second antenna group 5, or
another antenna group is newly arranged.

Next, in Fig. 2, a receiving portion 12 is connected

to a specific antenna 11 in a first antenna group 1, and a receiving portion 22 and a first phase shifter 31 are sequentially cascade-connected to another antenna 21. A first adder 32 is connected between the output terminal of the receiving portion 12 and the output terminal of the first phase shifter 31. An A/D converter 30 is connected to the next stage of the first adder 32. A power detecting means 33 and a specific OFDM demodulating means 35 are connected to the next stage of the A/D converter 30. A phase control means 34 is connected between the power detecting means 33 and the first phase shifter 31.

On the other hand, a receiving portion 52 is connected to a specific antenna 51 in a second antenna group 5, and a receiving portion 62 and a first phase shifter 71 are sequentially cascade-connected to another antenna 61. A first adder 72 is connected between the output terminal of the receiving portion 52 and the output terminal of the first phase shifter 71. An A/D converter 70 is connected to the next stage of the first adder 72. A power detecting means 73 and another OFDM demodulating means 75 are connected to the next stage of the A/D converter 70. A phase control means 74 is connected between the power detecting means 73 and the first phase shifter 71.

A third adder 93 is connected to the next stage of the specific OFDM demodulating means 35. A second phase shifter 92 is connected to the next stage of another OFDM

demodulating means 75. A third adder 93 is connected to the next stage of the second phase shifter 92. Here, the specific OFDM demodulating means 35 is distinguished from another OFDM demodulating means 75 because no second phase shifter 92 is interposed between the specific OFDM demodulating means 35 and the third adder 93.

A phase control means 91 is arranged between the output terminal of the specific OFDM demodulating means 35 and the output terminal of another OFDM demodulating means 75, and its output terminal is connected to the second phase shifter 92.

In the above construction, the A/D converters 30, 70 mutually have the same construction, and convert an intermediate frequency signal to a digital base band signal of a time area.

Here, the intermediate frequency signal outputted from the receiving portion 12 corresponding to the specific antenna 11 is directly inputted to the first adder 32 corresponding to the first antenna group 1. The intermediate frequency signal outputted from the receiving portion 22 corresponding to another antenna 21 is inputted through the first phase shifter 31. In this case, the phase of the first phase shifter 31 is set by the phase control circuit 34 such that signal electric power detected by the power detecting means 33 becomes maximum. As this result, the phase of the intermediate frequency signal inputted from the first phase shifter 31 to the

first adder 32 and the phase of the intermediate frequency signal inputted from the receiving portion 12 to the first adder 32 are conformed to each other. Namely, diversity synthesis is made at the stage of the intermediate frequency signal. Accordingly, the intermediate frequency signal having maximum electric power is inputted to the A/D converter 30. The base band signal of the time area converted by the A/D converter 30 also has maximum electric power, and is inputted to the specific OFDM demodulating means 35.

Similarly, the intermediate frequency signal outputted from the receiving portion 52 corresponding to the specific antenna 51 is directly inputted to the first adder 72 corresponding to the second antenna group 5. The intermediate frequency signal outputted from the receiving portion 62 corresponding to another antenna 61 is inputted through the first phase shifter 71. In this case, the phase of the first phase shifter 71 is set by the phase control circuit 74 such that signal electric power detected by the power detecting means 73 becomes maximum. As this result, the phase of the intermediate frequency signal inputted from the first phase shifter 71 to the first adder 72 and the phase of the intermediate frequency signal inputted from the receiving portion 52 to the second adder 72 are conformed to each other. Namely, the diversity synthesis is made at the stage of the intermediate frequency signal. Accordingly, the

intermediate frequency signal having maximum electric power is inputted to the A/D converter 70. The base band signal of the time area converted by the A/D converter 70 also has maximum electric power, and is inputted to
5 another OFDM demodulating means 75.

Accordingly, it is easy to take synchronization for Fourier-transforming the base band signal of the time area in each of the OFDM demodulating means 35, 75. The base band signal of a frequency area is outputted from each of
10 the OFDM demodulating means 35, 75.

The constructions and the operations of the latter stage sides of the specific OFDM demodulating means 35 and another OFDM demodulating means 75' are the same as Fig. 1, and their explanations are therefore omitted. Since the
15 diversity synthesis is made at the stage of the intermediate frequency signal in the construction of Fig. 2, the number of A/D converters becomes half.

In Fig. 3, a specific antenna 11 is directly connected to a first adder 32 corresponding to a first
20 antenna group 1, and another antenna 21 is connected through a first phase shifter 31. A receiving portion 10 and an A/D converter 30 are sequentially cascade-connected to the first adder 32. A power detecting means 33 and a specific OFDM demodulating means 35 are connected to the
25 next stage of the A/D converter 30. A phase control means 34 is connected between the power detecting means 33 and the first phase shifter 31.

On the other hand, a specific antenna 51 is directly connected to a first adder 72 corresponding to a second antenna group 5, and another antenna 61 is connected through a first phase shifter 71. A receiving portion 50 and an A/D converter 70 are sequentially cascade-connected to the first adder 72. A power detecting means 73 and another OFDM demodulating means 75 are connected to the next stage of the A/D converter 70. A phase control means 74 is connected between the power detecting means 73 and the first phase shifter 71.

Accordingly, a high frequency signal received by the specific antenna 11 is directly inputted to the first adder 32, and a high frequency signal received by another antenna 21 is inputted through the first phase shifter 31. In this case, the phase of the first phase shifter 31 is set by the phase control circuit 34 such that signal electric power detected by the power detecting means 33 becomes maximum. As this result, the phase of the high frequency signal inputted from the first phase shifter 31 to the first adder 32 and the phase of the high frequency signal inputted from the specific antenna 11 to the first adder 32 are conformed to each other. Namely, the diversity synthesis is made at the stage of the high frequency signal. Accordingly, the high frequency signal having maximum electric power is inputted to the receiving portion 10. The base band signal of the time area converted by the A/D converter 30 also has maximum

electric power, and is inputted to the specific OFDM demodulating means 35.

Similarly, a high frequency signal received by the specific antenna 51 is directly inputted to the first adder 72, and a high frequency signal received by another antenna 61 is inputted through the first phase shifter 71. In this case, the phase of the first phase shifter 71 is set by the phase control circuit 74 such that signal electric power detected by the power detecting means 73 becomes maximum. As this result, the phase of the high frequency signal inputted from the first phase shifter 71 to the first adder 72 and the phase of the high frequency signal inputted from the specific antenna 51 to the first adder 72 are conformed to each other. Namely, the diversity synthesis is made at the stage of the high frequency signal. Accordingly, the high frequency signal having maximum electric power is inputted to the receiving portion 70. The base band signal of the time area converted by the A/D converter 70 also has maximum electric power and is inputted to the specific OFDM demodulating means 75.

Accordingly, it is easy to take synchronization for Fourier-transforming the base band signal of the time area in each of the OFDM demodulating means 35, 75. The base band signal of a frequency area is outputted from each of OFDM demodulating means 35, 75.

The constructions and the operations of the latter

stage side of the specific OFDM demodulating means 35 and another OFDM demodulating means 75 are the same as Fig. 1, and their explanations are therefore omitted. Since the diversity synthesis is made at the stage of the high
5 frequency signal in the construction of Fig. 3, the number of receiving portions becomes half as well as A/D converters.

As explained above, OFDM demodulating means are arranged every plural antenna groups, and a first phase
10 shifter is arranged on the former stage side of each of the OFDM demodulating means, and a second phase shifter is arranged at the latter stage of another OFDM demodulating means except for a specific OFDM demodulating means, and a signal is diversity-synthesized by the first phase shifter
15 until the base band signal of a time area is inputted to each of the OFDM demodulating means, and the base band signal of a frequency area outputted from each of the OFDM demodulating means is diversity-synthesized by the second phase shifter. Accordingly, it is easy to synchronize the
20 base band signal of the time area in the OFDM demodulating means, and cost can be reduced by reducing the number of OFDM demodulating means.

The base band signal of the time area based on a high frequency signal received by a specific antenna in each of
25 the antenna groups, and the base band signal of the time area based on a high frequency signal received by another antenna except for the specific antenna are diversity-

synthesized by the first phase shifter. Accordingly, the base band signal of the time area having maximum electric power can be inputted to each OFDM demodulating means.

A receiving portion for frequency-converting the high
5 frequency signal to an intermediate frequency signal, and
an A/D converter for converting the intermediate frequency
signal to a digital signal and outputting the base band
signal of the time area are arranged every each of the
antennas, and the first phase shifter is arranged at the
10 next stage of the A/D converter corresponding to another
antenna, and a first adder is arranged between the first
phase shifter and the A/D converter corresponding to the
specific antenna. Accordingly, the base band signal of the
time area can be diversity-synthesized.

15 An intermediate frequency signal based on the high
frequency signal received by the specific antenna in each
of the antenna groups, and an intermediate frequency
signal based on the high frequency signal received by
another antenna except for the specific antenna are
20 diversity-synthesized by the first phase shifter.
Accordingly, the number of A/D converters can be reduced.

A receiving portion for frequency-converting the high
frequency signal to the intermediate frequency signal is
arranged every each of the antennas, and the first phase
25 shifter is arranged at the next stage of the receiving
portion corresponding to another antenna, and a first
adder is arranged between the receiving portion

corresponding to the specific antenna and the first phase shifter. Accordingly, the intermediate frequency signal can be diversity-synthesized.

5 The high frequency signal received by the specific antenna in each of the antenna groups, and the high frequency signal received by another antenna except for the specific antenna are diversity-synthesized by the first phase shifter. Accordingly, the number of receiving portions can be reduced.

10 The first phase shifter is connected to another antenna, and a first adder is arranged between the specific antenna and the first phase shifter. Accordingly, the high frequency signal can be diversity-synthesized.

Power detecting means for detecting electric power of
15 the base band signal of the time area, and phase control means for controlling phase setting of the first phase shifter so as to maximize the electric power are arranged. Accordingly, the diversity synthesis for maximizing the electric power of the base band signal of the time area
20 can be made.

The second phase shifter is arranged at the next stage of another OFDM demodulating means, and a second adder is arranged between the specific OFDM demodulating means and the second phase shifter. Accordingly, it is
25 possible to make the diversity synthesis with respect to the high frequency signal received by all the antennas.

The OFDM receiver further has phase control means for

controlling phase setting of the second phase shifter such that the phase of the base band signal of the frequency area outputted from the second phase shifter is conformed to the phase of the base band signal of the frequency area
5 outputted from the specific OFDM demodulating means. Accordingly, the base band of the frequency area can be diversity-synthesized.